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ABSTRACT

To increase enrollment in high school science classes and, thereby, increase scientific literacy among Americans, efforts must begin in elementary and middle schools. The Blue Mountain Small School Consortium, nine small and rural schools in southeastern Washington, cooperated with Whitman College in a search for improved methods of teaching elementary school science. Initial teacher surveys identified factors detrimental to elementary science instruction: (1) inadequate teacher knowledge of science content and appropriate teaching methods; (2) equipment and related budget problems; (3) lack of appropriate curriculum materials with sufficient structure; and (4) a belief that science is a lower priority than other curriculum areas. The first inservice staff development efforts were summer courses demonstrating a model of science teaching and learning that recognizes: (1) curiosity as the fundamental driving force in science; (2) the process orientation of science; (3) no one "scientific method"; (4) willingness to change conclusions in the light of new evidence; and (5) a faith in the susceptibility of the environment to human ordering and understanding. Despite high evaluations of this coursework, there was no significant improvement in the amount and quality of science instruction observed. Current efforts focus on creating structured instructional materials as teacher aids. These traveling instructional kits are shared among member schools and therefore eliminate many previous equipment problems. Accompanying lesson plans attempt to provide sufficient guidance for the teacher who needs help while allowing room for expansion by the more ambitious teacher. (SV)

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NETWORKING SCIENCE TEACHING IN SMALL AND RURAL SCHOOLS

What should be taught in elementary school science, and how it should be taught, are recurring questions in both professional journals and the popular press. An article in Educational Leadership begins: "Should we teach science as a review of what scientists know or as something which students can use?" (Yager, 1988). The author answers his question by stating that "Teachers should promote student involvement, ... , by posing questions and problems relevant for the students." To Yager, elementary science is based on the premise that students acquire knowledge because they need it, not because the teacher insists it will be useful later. However they acquire their knowledge of science, it would appear that students don't learn enough. One newspaper article asserts that "...only about 10 percent of adult Americans could be considered scientifically literate." (Spokesman-Review Spokane Chronicle, 1986). The article defines literacy thusly "...most experts believe scientific literacy means more than mastery of scientific facts." The 1983 report A Nation At Risk, speaking to the same problem, recommended that high school graduation requirements be increased and, at a minimum, students be required to take three years of science in high school. The phenomena of decreased enrollment in elective high school science courses is well documented; understanding the decline requires examination of how students view science and its importance to their lives. Evidence indicates that these feelings are based, at least in part, upon the kind of experiences students have had in science before they reach high school.

In a recent report, then Secretary of Education Bennett stated that by the fourth grade, a majority of students were turned off to the study of science. Combining that assertion with the decline in enrollment in high school classes would lead to a hypothesis that increasing scientific literacy begins with more effective forms of science instruction in elementary and middle school classrooms.

That change is needed is well documented. In summarizing a program called Project Synthesis, Penick and Yager list the following information:

"1) There is a mismatch between the science curriculum found in schools and that which 90% of the students need and want.

2) Nearly all science teachers (90%) emphasize goals for school science that are directed only toward preparing students for further formal study of science.

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4) Over 90% of all science teachers use a textbook 95% of the time; hence, the textbook becomes the course outline, the framework, the parameters for student's experiences, testing, and a world view of science.
5) There is virtually no evidence of science being learned by direct experience.
6) While much effort has centered on writing textbooks, there has been little or no attention to the development of a true science curriculum, encompassing goals, materials, classroom environment, and teaching strategy.
8) There is no evidence that science in its most basic sense is ever approached in school science." (Penick & Yager, 1986)

John Goodlad, in A Study of Schooling, provided further insight into why science is viewed so negatively by students.

"One would expect the teaching of social studies and science in schools to provide ample opportunities for the development of reasoning: deriving concepts from related events, testing in a new situation hypotheses derived from examining other circumstances, drawing conclusions from an array of data, and so on. Teachers listed those skills and more as intended learning. We observed little of the activities that their list implied, and teachers' tests reflected quite different priorities--mainly the recall of information." (Goodlad, 1983)

The result of all this, according to Goodlad is that "No academic subject ranked above fourth place for interest at the secondary level."

Another finding cited by Goodlad is that data are relatively consistent from school to school. He states it thusly: "It appears, then, that a rich, detailed body of data on even a small sample of representative schools can shed much light on problems and issues that may be endemic to schooling." (Goodlad, 1983) This information supports the contention that small and rural schools are not markedly different from their urban counterparts. Certain problems may be exacerbated by conditions in small or rural schools, just as certain problems are of much greater consequence in an inner-city school. Teacher isolation is a problem in all schools but it is more direct in a school which has only two or three teachers, or at best one teacher per grade in K-6. In curriculum areas like science, not having someone to ask or share concerns with can reduce even further the willingness to make a special effort and teach science as it should be taught.

Goodlad goes on to assert that if one seeks to improve education one must first understand the context in which that education is taking place.

"Committed to the factory model without feeling the need to validate it, our reflex response to school problems as citizens and educators is to increase pressure through mandates, testing requirements, new standards for college entrance, and the like. We rarely look at what lies between the input valve and the output spigot. To treat even

something as simple as frozen water pipes in this manner would be to court disaster. The interactions of individuals and other elements in and around schools are far more complicated than the interaction of cold air with water pipes. Strategies for school improvement that ignore these interactions and the rationales governing them are unlikely to have more than minimal impact on the culture of schools." (Goodlad, 1983)

As noted above, the interactions of teachers and students in science classes are often less than ideal. Seeking 'strategies for school improvement' is one of the goals which propelled the formation of a consortium of nine small and rural schools located in the SE corner of the state of Washington. Originally formed as a strategy to counter school consolidation movements, the school superintendents who created the Blue Mountain Small Schools Consortium (BMSSC) decided to cooperatively seek solutions to other problems after the consolidation crisis abated. In pursuing alternative methods of providing staff development and inservice opportunities to teachers, the BMSSC approached Whitman College. As a private, undergraduate liberal arts institution, the ability of the college to provide these types of services seemed problematic. Although the college does have a teacher education program, it does not offer any graduate programs and had not offered a summer program of classes since 1973. Recognizing an opportunity to expand its services to local schools, the college and BMSSC entered into a two-year trial agreement, in which the college agreed to develop a program of summer courses for teachers.

BMSSC/WHITMAN INSERVICE AND STAFF DEVELOPMENT

Promoting good teaching in all areas of the curriculum, as one major factor in increasing student achievement, is a primary goal of this collaborative effort. The search for methods which would work to enhance and increase the incidence of effective teaching in elementary school science provided the problem focus. In initial planning, factors which adversely affect teaching of elementary school science in BMSSC schools were listed. These are: 1) the concern that teachers felt regarding their own knowledge level in science content; 2) equipment and related budget problems. Equipment problems included both situations where no equipment was available and no money existed for purchase and situations where equipment was available but teachers did not use it, for various reasons; 3) not having curriculum materials available which provide sufficient structure to enable teachers to teach the type of science desired; and, 4) a belief that science instruction occupies a lower priority than do other areas of the curriculum. The creation of curriculum/science materials kits represents the BMSSC's second cycle of attempts to meet these key problems. The first inservice/staff development efforts focused on presenting a more traditional-style staff development program for teachers.

TEACHER KNOWLEDGE OF SCIENCE AND PEDAGOGY

Porter and Brophy define teacher knowledge as one component of good teaching.

> "Teacher knowledge is represented as encompassing (1) knowledge about the content to be taught, (2) knowledge about pedagogical strategies for teaching the content, and (3) knowledge about the students (in particular, about student background knowledge that can be capitalized upon and about student misconceptions that will need to be confronted during teaching). Good teaching requires possession and use of all three of the categories of teacher knowledge, not just knowledge of subject matter." (Porter & Brophy, 1987)

Porter and Brophy address the question of elementary teachers and science knowledge directly. They state "Elementary teachers tend to be ... typically weak in knowledge about science."

Based upon data from a needs assessment survey of all teachers in the nine BMSSC schools, a decision was made to emphasize science and mathematics in the summer program. To provide content knowledge in science and updated pedagogy, summer programs in 1986 & '87 offered courses in four areas of science: Biology, Chemistry, Earth Science, and Physics. Courses in methodology of teaching science were also offered. Funding was obtained from a series of Title II--Education for Economic Security grants, and combined with tuition waivers by the college, enabled the program to bypass problems with high tuition costs of the college.

Along with the goal of increasing content knowledge and pedagogical skills, the staff development courses sought to build and demonstrate a model of science teaching and learning which is the antithesis of the science teaching cited in Project Synthesis above. The type of science which this project seeks to promote has been defined by Lawrence Scharmann as:

> "(1) curiosity is the fundamental driving force in science; (2) science is process-oriented; (3) science aims at simplification and ever-increasing comprehensiveness;(4) there is no one scientific method as often described in school science textbooks;(5) science is characterized by a few attributes which focus more on values than techniques;(6) science is a faith in the susceptibility of the environment to human ordering and understanding;(7) science possesses a unique attribute of openness and willingness to change conclusions in light of new evidence; and (8) science is characterized by uncertainty and tentativeness." (Scharmann, 1988)

All inservice and staff development activities in the BMSSC were designed to provide the specific teacher knowledge listed by Porter and Brophy. Despite the relative success of these efforts, as indicated by teacher enrollment in summer courses and their evaluations of the coursework, significant improvement in the amount and quality of science instruction did not result. It is

hypothesized that either the courses failed to provide teachers with sufficient knowledge, particularly in science content and pedagogy, to enable them to improve their science teaching, and/or, other-factors operate to negatively affect science instruction.

Since the more traditional courses had failed to meet the goal of increasing the amount and effectiveness of science teaching, other avenues had to be explored. The projected solution was to provide the teacher with instructional materials which contain sufficient structure to help him/her feel comfortable in teaching the lessons. This approach recognizes the importance of teacher knowledge but supplies the deficit with carefully structured lessons that relieve teachers of their feeling that they must be an Einstein to effectively teach science to children. Even when a program is able to help teachers overcome their concerns about science knowledge, it still must address those problems associated with equipment dependent instruction.

EQUIPMENT PROBLEMS

Science equipment poses significant problems for many elementary school teachers. Getting the necessary materials is often the most basic concern. Beakers, graduated cylinders, and magnifying glasses are expensive and in times of tight budgets, science equipment is often given low priority. And even those teachers who have the needed equipment have problems with storage, getting it passed out to students and collected again after the lesson. Rural schools also face the unique problem of being geographically isolated, making it difficult to obtain materials. Without someone with expertise in science, the very task of ordering science equipment can be an overwhelming one.

The idea of creating traveling science kits had its beginning when all of the BMSSC schools pooled together the small grants which each received under Title II Math and Science program. Based on student enrollment, most of the dollar amounts were too small to be meaningful by themselves (the smallest was $29.00). Joined together with those of other BMSSC schools, however, the grants made a significant total. This money was used to purchase science materials for construction of kits to be used by all schools in the BMSSC.

The instructional kits are planned so as to eliminate as many of the equipment problems associated with using activity based science lessons as possible. The only action required of the classroom teacher who uses the kit is to replenish consumable materials before the kit is returned to storage. The kits are designed to be fully comprehensive, containing all of the materials needed for the planned lessons. Non-consumable materials are sturdy and damage proof to minimize need for replacement. An inventory list in the kit helps teachers regather all of the materials and return the kit with its full complement of materials. Kits are spot checked before they are sent to a school to ensure that no major equipment discrepancies exist. This system is functional only to the extent that teachers cooperate, however, since no formal structure exists to monitor condition of the kits.

In order to facilitate use of the kits, at present they are stored at the college, which while not geographically central, is centrally located. Teachers request the kit and it is sent to their school for use. At present no absolute time limits have been set, since the program is in its infancy, and demand is light. If the program develops as expected, demand could be met in different ways. If the kits prove popular enough to warrant it, they could be duplicated without costing too much. A second procedure would be to schedule each kit in a school in some sequence throughout the year. Teachers would know when the kit would be available and could thus plan their instruction accordingly. A smaller but related problem exists within the concept of a spiral curriculum. Since many of the materials in a kit are common to different activities, an example being magnets in the Magnets and Electricity kit, teachers of different grade levels must work cooperatively to make the materials kit system functional. Whether this will develop into a major problem is not known at this time. Further use of the system will be required to determine the magnitude of this and other problems.

CURRICULUM MATERIALS AND LESSON PLANS

The equipment kits would be incomplete if they did not provide teachers with some form of instructional outline or lesson plans. An obvious answer would be to select a science curriculum or text series which meets the needs of teachers. Given the diverse nature of BMSSC schools, each with a different cycle of textbook adoptions, such a selection would be very difficult at best. And, complicating the process was a failure to find a text series which contained the desired kinds of science experiences. Use of existing published material did not appear to offer a solution to the problem. A new approach was necessary to provide teachers with a support system which would enable them to overcome the problems they faced in teaching science to children.

If published curriculum materials are not available or are unsuitable, another option is to create such materials to meet specific goals and needs. In doing so, one must be cognizant of the problems created by 'teacher-proof curriculums' which hampered instructional improvements in science in the recent past. When such instructional packets are carefully crafted, however, they offer great potential benefit to teachers. While not speaking to science directly, Porter and Brophy describe such benefits thusly:

> " However, the implied assumption that teachers can do better working on their own with scarce time and meager financial resources is even more questionable. If teachers carefully select instructional materials to fit the curriculum goals and the characteristics of their students and then make extensive use of these materials, they will be able to devote most of their time and energy to practices that enrich the content through reinterpretation and expansion and that clarify the content through presentation, recitation, discussion, and evaluation activities." (Porter & Brophy, 1987)

It was clearly recognized that kits of science teaching

materials were a necessary but not sufficient condition for improving science instruction. A concomitant requirement was to provide instructional plans which met two criteria: 1) detailed enough to provide guidance for a teacher who needed a lot of help; and 2) with enough room for expansion and extension of learning to allow a teacher to go beyond the actual lesson plan. The intent of the kits is not to limit a teachers creativity in science but rather to offer a base of doable, proven, effective science experiences for children. Beyond that, a teacher can use the lessons and materials in any way he/she desires.

The kits also represent an attempt to establish continuity in science programs between grades. A commitment was made to provide the outline, at least, of a spiral curriculum in each topic. Each kit provides learning activities which build on a common theme, such as water, and provide learning experiences at different grade levels. Through the continued study of major concepts in science, at increasing levels of complexity students will, it is hoped, acquire a deeper understanding of the concepts.

The task of helping teachers obtain maximum benefit from the kits is still in progress. Ideally, no teacher would be allowed to teach lessons from the kit without some form of inservice. The reality is such that this will remain a goal for the near future at least. As a substitute, BMSSC has begun a program to videotape the lessons being presented in a classroom, so that teachers may, if they wish, view the lesson being taught by a master teacher. Hopefully this will enable them to feel more comfortable with the lesson content, its goals and objectives, and the activities which build the desired knowledge and skill in students. Access to a science consultant at the college level is also intended to help teachers overcome whatever problems they encounter in using the kits. It is quite likely that lesson plans will need to be rewritten as teachers identify problem areas within the instructional sequence.

EVALUATING THE PROJECT

Unfortunately, most questions about this effort to positively affect elementary science instruction in a consortium of small and rural schools remain unanswerable at this time. The program is too new for the gathering of any evaluative data. Only continued use of the curriculum guides and material kits will enable judgments of the effectiveness of the program. On a macro level, the number of times the kits are used by teachers will provide rough evaluative data. Further evaluation efforts could focus on student achievement and changes in their conception of the importance of science and their attitudes towards it. Final evaluation of the effectiveness of the kits will come, however, only through a longitudinal study which documents the future actions of those students who study science, at least in part, out of the kits. The ultimate decision criterion will be whether these students elect to study science in high school at a rate greater than have their peers in the past. Short term evaluations, such as changes in attitude or knowledge of science as measured on standardized tests do not provide the meaningful kinds of information on which to

judge these types of improvement efforts. The ultimate goal remains that of increasing scientific literacy among our citizens; this requires that students take more, and hopefully more effective, science courses in high school.

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